UNIVERSITY OF CALIFORNIA PUBLICATIONS

COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
BERKELEY, CALIFORNIA

THE PRUNING OF CITRUS TREES IN CALIFORNIA

BY
ROBERT W. HODGSON

BULLETIN No. 363
MAY, 1923

UNIVERSITY OF CALIFORNIA PRESS
BERKELEY, CALIFORNIA
1923

DAVID P. BARROWS, President of the University.

EXPERIMENT STATION STAFF

HEADS OF DIVISIONS

THOMAS FORSYTH HUNT, Dean.
EDWARD J. WICKSON, Horticulture (Emeritus).
——— ———, Director of Resident Instruction.
C. M. HARING, Veterinary Science, Director of Agricultural Experiment Station.
B. H. CROCHERON, Director of Agricultural Extension.
C. B. HUTCHISON, Plant Breeding, Director of the Branch of the College of Agriculture, Davis.
H. J. WEBBER, Subtropical Horticulture, Director Citrus Experiment Station.
WILLIAM A. SETCHELL, Botany.
MYER E. JAFFA, Nutrition.
RALPH E. SMITH, Plant Pathology.
JOHN W. GILMORE, Agronomy.
CHARLES F. SHAW, Soil Technology.
JOHN W. GREGG, Landscape Gardening and Floriculture.
FREDERIC T. BIOLETTI, Viticulture and Fruit Products.
WARREN T. CLARKE, Agricultural Extension.
ERNEST B. BABCOCK, Genetics.
GORDON H. TRUE, Animal Husbandry.
WALTER MULFORD, Forestry.
JAMES T. BARRETT, Plant Pathology.
W. P. KELLEY, Agricultural Chemistry.
H. J. QUAYLE, Entomology.
ELWOOD MEAD, Rural Institutions.
H. S. REED, Plant Physiology.
L. D. BATCHELOR, Orchard Management.
W. L. HOWARD, Pomology.
*FRANK ADAMS, Irrigation Investigations.
C. L. ROADHOUSE, Dairy Industry.
R. L. ADAMS, Farm Management.
W. B. HERMS, Entomology and Parasitology.
JOHN E. DOUGHERTY, Poultry Husbandry.
D. R. HOAGLAND, Plant Nutrition.
G. H. HART, Veterinary Science.
L. J. FLETCHER, Agricultural Engineering.
EDWIN C. VOORHIES, Assistant to the Dean.

THE PRUNING OF CITRUS TREES IN CALIFORNIA

By ROBERT W. HODGSON

CONTENTS

FOREWORD

This bulletin, prepared by Robert W. Hodgson, formerly Instructor in Citriculture, now Specialist in Agricultural Extension and Farm Advisor of Los Angeles County, is a timely discussion of a subject of great interest to citrus growers.

No method or methods for the pruning of citrus trees can as yet be recommended that are based upon careful comparative experiments carried on over a period of years. The data from such experiments as have been conducted clearly indicate that severe pruning is injurious as compared with no pruning. They do not, however, indicate that no pruning is a safe policy to follow.

Mr. Hodgson's discussion and the methods suggested are based upon observational data accumulated over a number of years, together with a study of the methods pursued by some of the best and most successful citrus growers. It should be understood, however, that the methods outlined are not put forward as the final word on citrus pruning; more experimental data must be secured before methods can be recommended without reservation.

H. J. Webber,
Director, Citrus Experiment Station.

PART I. GENERAL PRINCIPLES

INTRODUCTION

Of the many separate operations which collectively constitute good practice in the growing of citrus fruits, none is of more interest to the grower than pruning. There is probably none concerning which there is so general a lack of knowledge. Certain it is that there is no commonly recognized orchard operation concerning which there is less agreement.

One school of pruners adheres to the practice of heavy annual cutting and claims markedly beneficial results. Another and larger group advises the practice of light to moderate pruning with claims of equally satisfactory results. A considerable and increasing number recommends confining pruning treatment to the cutting out of dead wood, interfering branches, and vigorous sucker shoots, with results that are stated to be all that could be desired.

The divergency of opinion among growers of citrus fruits concerning pruning is so remarkable as to warrant a brief analysis of its causes. The almost total lack of experimental data on this subject is partially responsible for the situation. The main contributing factor, however, has been the influence exerted by individual pruners here and there, who through observation and experience have developed rather definite systems. Through long use or the dominant personality of their originator certain of these have become well established in standard orchard practice. Citrus tree pruning practice in California has been developed largely on the basis of mechanical procedure rather than as a result of an understanding of the principles involved.

To the average grower, pruning is a purely mechanical operation, consisting of the removal of certain parts of the plant in varying amounts, usually practiced simply as a matter of custom. Of recent years a wholesome tendency to question the value of pruning has developed, with the result that a considerable number of growers have discontinued the practice until proof of its necessity shall be brought forward. The fact remains, however, that few growers have given the pruning problem more than a very superficial study, the majority confining their efforts to the attempt to master some purely mechanical system which is being used with reported success elsewhere.

Pruning is an operation which must be regarded as having a profound influence on the vital activities of the plant. Satisfactory results cannot reasonably be expected to follow mere perfunctory or mechanical cutting out of parts of the tree. Fundamental to an intelligent attitude on the part of the grower toward the pruning question is an understanding of the basic principles of plant physiology which affect growth and fruit production.

PHYSIOLOGICAL CONSIDERATIONS

It is a general axiom of plant physiology that those factors, climatic and otherwise, which favor vegetative growth are in the main antagonistic to fruit production. This principle has long been recognized, although until quite recently it was but poorly understood. Practical applications of this principle are many and varied. Thus it is the common observation that plants excessively luxuriant in growth set fruit but sparsely; in warm, humid climates trees and vines frequently grow to great size and have much foliage but bear little or no fruit; severe winter pruning of the type which favors a vegetative response is usually followed by decreased fruit production.

On the other hand, it is equally true that those conditions which in general act as a check to vegetative growth increase the tendency to fruit production. A decrease in water supply may accentuate the fruit-bearing tendency; certain types of summer pruning tending to check vegetative growth appear to favor fruit production. The chief function of life is reproduction and fruit trees seem to be no exception to the rule. It appears that as long as conditions favor vegetative growth the reproductive tendency is but little expressed but when conditions change, becoming less favorable to vegetative growth, the reproductive tendency becomes more and more apparent.

Other things being equal, the amount of fruit produced depends on a relation which exists between those factors favorable to vegetative growth and those conditions favoring fruit production. This equilibrium varies considerably for the same variety in different localities and also from season to season in the same district. Where no artificial interruptions occasioned by man or other agencies intervene, the season fluctuation in equilibrium between these two opposing sets of factors is reflected in the amount of crop produced.

NUTRITIONAL FACTORS

A further analysis of certain of the factors which influence vegetative growth and fruit production is desirable as a basis for a correct understanding of the pruning problem. What are the conditions which favor fruit production and what are those which restrict it? For convenience they may be divided roughly into two classes, climatic and cultural. Of the climatic factors probably the most important are light intensity and duration, temperature, and humidity. Up to a certain degree of intensity these factors stimulate and encourage vegetative growth; beyond that point they become increasingly less favorable to vegetative growth and more conducive to fruitfulness. With our present knowledge we are unable to distinguish sharply the point at which this transition occurs. It appears to vary markedly for different plants.

Of other factors affecting the fruit-bearing tendency by far the most important are those having to do with nutritional considerations. The relation of food supply to fruit production and its importance to the pruning problem warrant a brief review of the physiological processes which constitute normal plant nutrition. The bulk of the plant substance, particularly of woody plants such as trees, is composed of carbon, the source of which is the carbon dioxide of the atmosphere. This is taken in by the leaves where, in the presence of the green coloring matter and of light, it is combined with water to form carbohydrates which serve as the main source of energy for the processes of metabolism and growth. Therefore, if the plant is to grow and develop normally, there must be a large and actively functioning leaf surface, a fact long recognized by plant physiologists but still not sufficiently appreciated by fruit growers.

Of far less bulk, in fact only a fraction in comparison, is that part composed of the constituents taken from the soil. Of these, there is general agreement among physiologists and growers to the effect that nitrogen is the most important because it is the one most likely to become deficient.

Recent researches of Kraus and Kraybill* are helpful in making clearer important and practical considerations with respect to the nutritive balance existing in plants. These researches have set forth in simpler terms the essential relation of plant nutrition to the equilibrium between three groups of substances; water, absorbed by the

* E. J. Kraus and H. R. Kraybill, Vegetation and Reproduction with Special Reference to the Tomato, Bull. 149, Oregon Agricultural Experiment Station, 1918.

roots and acting as the carrier for all food materials; carbohydrates, manufactured in the leaves; and nitrogenous compounds, absorbed in dissolved form in the soil solution.

Assuming that water is present at all times in sufficient amounts—a requirement that is generally recognized by growers—these investigators have discovered strong evidence that the fruit-bearing propensity is most intimately associated with the ratio existing in the plant between the amount of carbohydrates manufactured and the nitrogenous compounds taken up by the roots. On this basis they have been able to establish four general classes into which may be grouped the tendencies of plants toward vegetation and reproduction with respect to the carbon-nitrogen ratio.

Optimum Fruitfulness.—The optimum condition of fruitfulness of value to the orchardist is that in which the nitrogen needs of the plant are satisfied and in which a sufficient surplus of carbohydrates is manufactured to occasion the storage of reserve supplies.

Vegetative Growth.—It has been shown that where the nitrogen supply is ample but the synthesis of carbohydrate materials sufficient only to take care of growth needs without providing for the accumulation of surplus for storage, vegetative growth occurs, accompanied by the production of little or no fruit.

Nitrogen Starvation.—Where the nitrogen supply is deficient, even though carbohydrate surpluses exist, vegetation and reproduction are both lessened and a condition of disease exists, the characteristic symptoms of which are small, yellowish or gray foliage, slender, short, and brittle shoots or twigs, and frequently an abundance of undersized buds or flowers of which a very few mature.

Carbohydrate Starvation.—Even though the nitrogen supply is ample, if the supply of carbohydrates is deficient, vegetative tendencies are repressed and unfruitfulness results. Plants in this condition are generally of weak, aenemic growth, with pale yellowish foliage, and frequently are characterized by total failure to produce flowers or fruit.

SOME APPLICATIONS

Applications of these nutritional relations will at once occur to the observant orchardist. A few of them will be reviewed briefly.

A consideration of these principles clearly indicates the dangers which accompany severe pruning of healthy, vigorously growing trees, since such treatment occasions carbohydrate starvation. These principles also serve to make clear the cycles through which the tree normally passes from the time of planting until decadence occurs. In

a fertile soil the young tree finds the nitrogen supply ample. Carbohydrate synthesis being small, however, on account of relatively small leaf area, the result is that the first few years of its life are spent in vegetative growth. As carbohydrate manufacture increases with an ever-expanding leaf surface, the point is reached ultimately where a surplus accumulates and optimum fruitfulness occurs. As the tree continues to develop, if the nitrogen supply in the soil is not maintained through fertilization, this element eventually becomes deficient and decadence from nitrogen starvation occurs. If the nitrogen supply is maintained, however, while conditions exist which occasion either a diminution in leaf area or a decrease in photosynthetic efficiency, carbohydrate starvation occurs and unfruitfulness and decline result.

It can thus readily be seen why it is that pruning during the early years prolongs the period of vegetative growth and delays the time when the tree comes into bearing. It is also apparent why heavy pruning of trees in good fruit-bearing condition tends to repress fruitfulness and induces vegetation. The reason also becomes evident why old and deteriorating trees may sometimes be brought back into bearing by means of pruning treatment which is of a character designed either to reduce the carbon-nitrogen ratio to the point where fruitfulness results or to eliminate tissues of decreased photosynthetic efficiency and to substitute therefor new and more efficient carbohydrate-manufacturing leaf surface. These considerations also serve to explain the well-known response of certain types of decadent trees to nitrogen fertilization.

In the light of these principles it also becomes readily apparent why the navel orange variety has a tendency to heavy bloom in the interior valley sections where the light intensity and exposure are such as to markedly stimulate photosynthetic activity. Other and hitherto similarly unexplainable phenomena at once become understandable, such as the fact that gophered trees or trees affected with trunk or root diseases so frequently bear extraordinary crops just prior to their death.

But perhaps the most important lesson to be drawn from these principles is their application to orchard practice in such a manner as to maintain that ratio between nitrogen intake and carbohydrate assimilation under which optimum fruitfulness occurs. The maintenance of this nutritional balance at all times should be the aim of the grower, and cultural practices used should be analyzed in the light of their relation to this balance. By way of illustration let us consider the

case of trees in a condition of nitrogen starvation where the nitrogen-carbon ratio is such that little or no fruit is produced. This condition may be remedied in one of two ways, either by reducing the supply of carbohydrates by means of pruning, or by increasing the nitrogen supply by means of fertilizer applications. Although either method accomplishes the desired end, obviously the latter practice is the correct one to follow, since nitrogen fertilization makes possible greater use of the carbohydrate supplies already available and thus provides for the production of a larger quantity of fruit than is possible where fruitfulness is induced through reduction of carbohydrate manufacture by means of pruning.

DEFINITION AND OBJECTS

The removal of any vegetative plant part may be regarded as pruning, irrespective of the objects in mind or the effects on the plant. In general the function of pruning is that of regulating the growth of shoots by determining their location, kind, and number.

The two general objects of pruning are (1) to give the plant a desired shape, and (2) to establish and maintain that relation between vegetative and reproductive tendencies which produces optimum results for the grower. The first object, the development of a desired form, is of special importance during the early years, and is usually referred to as 'training.' The second object is materially influenced by the interests of the grower. Objects frequently mentioned, for which pruning is believed to be necessary, include increase in production, regulation of amount of crop, improvement of quality, convenience in harvesting, and the maintenance of longevity. In the case of citrus trees there is general agreement that the pruning problem consists of: (1) the establishment of a strong framework system, and (2) the maintainance of a balance between vegetative vigor and fruitfulness which is conducive to the economical production of maximum crops of best quality while consistent with the maintenance of tree health.

In the light of the discussion of general principles presented, it may be seen that pruning is but one of a number of operations which may be used by man in the regulation of the nutritional balance in plants. Pruning should be looked upon as fundamentally an operation concerned with regulation of food supply and storage, and its effects on the plant should be therefore regarded as the results of changes in environment. Properly used, pruning may be a valuable aid to man in his efforts to secure profitable fruit crops.

PART II. PRUNING CITRUS TREES

REASONS FOR PRUNING

In the past the general practice in the pruning of citrus trees in California has undoubtedly been too great severity, and the economic waste which has resulted from severe pruning has been very great. Recognizing this fact, the growers, particularly the larger growers, have in recent years been showing a tendency to prune much less. In fact, in the minds of some growers, there is doubt as to whether citrus trees in California require any pruning treatment whatever. While the tendency toward less pruning is admittedly wholesome and amply justified both by experimental evidence and observational data, yet to discontinue pruning altogether is probably going too far. Sufficient evidence is at hand to warrant the continuance of light or moderate pruning as a means of efficient citrus fruit production.

Among the factors bearing on the need for pruning citrus trees in this state, the two of greatest importance have to do with lessened costs of production and the maintenance of tree health and longevity. Under favorable conditions of soil and climate unpruned trees are almost certain eventually to become too large for the most economical handling, for it is generally recognized that there is a certain size of tree above which the costs of production increase faster than the returns from the additional fruit produced (figs. 1, 2, and 3). These increased costs are principally those of harvesting the fruit, which increases notably with the height of the tree, and those of fumigation and spraying, which increase in proportion to the volume of the tree and with large trees reach an almost prohibitive figure. To the owner of the young orchard, or even of the average bearing orchard, the problem of the oversized tree is not yet apparent. There are a goodly number of old orchards, however, where this problem is a very real one, a problem capable of solution only by means of judicious pruning.

In practically all districts unpruned citrus trees become so dense that sunlight is excluded from their interior, with a consequent loss of fruit bearing in that part of the tree. The fruit on such trees is carried mainly on the outer parts as a 'shell' crop, where it is subject to wind scarring, sunburn, fumigation injury, and other vicissitudes

which result in a high percentage of cull fruits. Large trees with the fruit practically all borne on the outside are not desirable, since the bearing surface is not efficiently utilized. Smaller trees, kept reasonably open to the entrance of light by means of pruning, will bear as much or even more fruit of distinctly better average quality.

Fig. 1.—Thirty-year old Valencia trees forty feet tall, never pruned and too large for economical handling.

While the reasons for it are as yet unexplained, there is no disputing the fact that in nearly all citrus varieties certain vigorous types of growth occur which experience has shown to be undesirable. The necessity for pruning as a means of eliminating these is generally recognized by growers, who point to the 'wild tops' and 'two story

trunks' of unpruned navel trees, and the long, spindling, mechanically weak branches and decadent tops of unpruned Valencia orange and lemon trees as evidence of what is likely to occur where pruning is not done. As a means of maintaining citrus trees in good health over

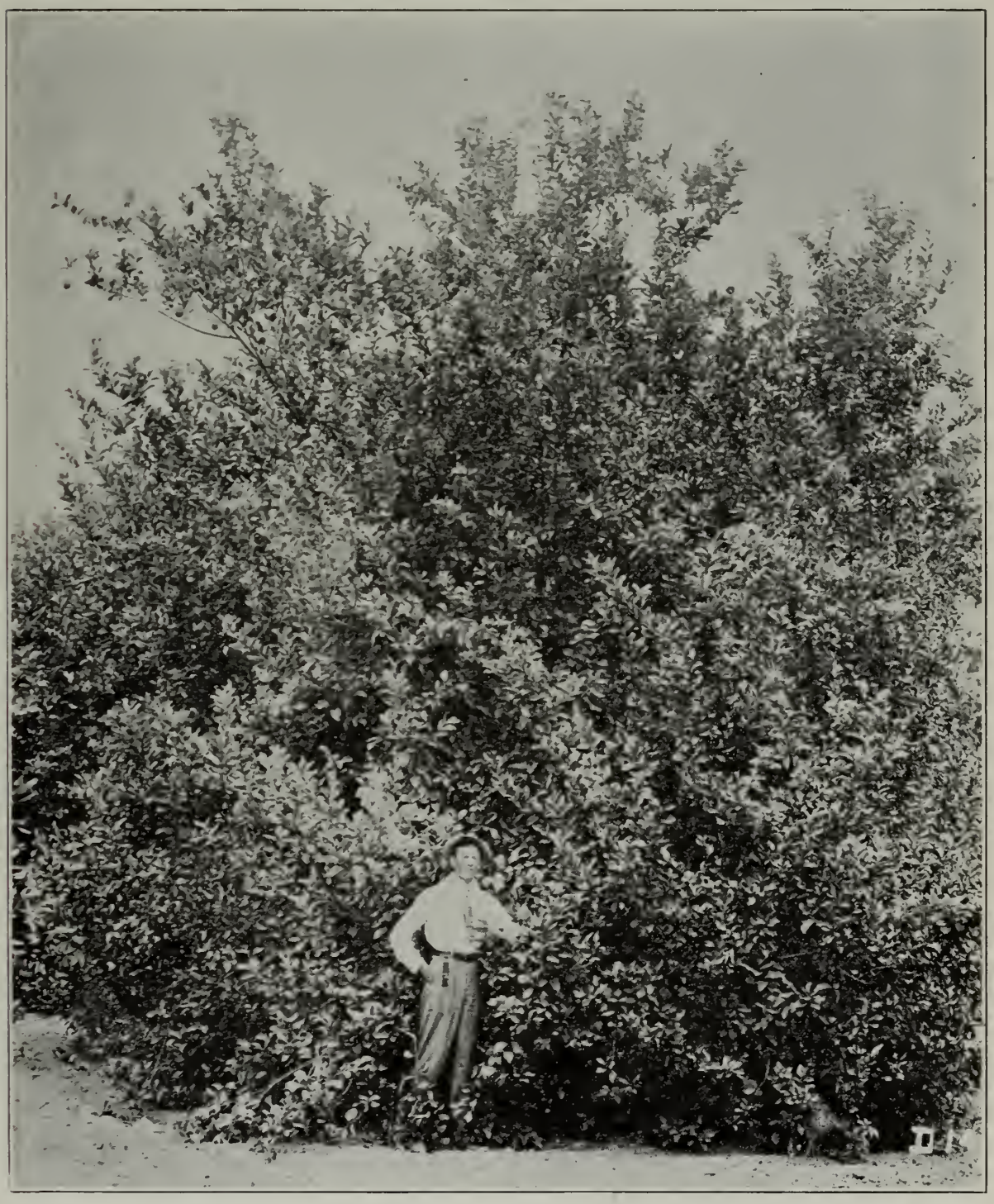

Fig. 2.—Thirty-year-old lemon tree, never pruned and nearly thirty feet tall. Too large for greatest economy. (Photo by courtesy of the Citrus Experiment Station.)

a long period of time, and as an aid in the production of satisfactory crops at a reasonable cost, there is no question that pruning is both a necessary and desirable practice.

Training treatment for the young tree, particularly with certain varieties, is necessary if a strong framework, capable of holding up the heavy weight of fruit which the trees will later carry, is to be developed. A large part of the expensive propping and bracing of citrus trees now practiced extensively in certain sections could be

Fig. 3.—Old unpruned lemon trees with branches interlacing. Pruning for convenience in fumigating is greatly needed.

dispensed with had the trees been given proper training treatment in their early years. In sections where wind prevalence is high this early training is of especial importance. The occasional occurrence of severe fall and winter storms with heavy losses from breakage in practically all citrus districts, however, clearly indicates the desirability of closer attention to this phase of the problem.

COMPLICATING FACTORS

There are a number of factors bearing on the pruning of citrus trees which have occasioned confusion in the minds of growers, the recognition of which is helpful in securing a proper attitude toward the subject. It is certain that the problem of pruning citrus trees is less well understood than that of pruning deciduous trees, one of the reasons being the fact that citrus trees are evergreens, a group of

Fig. 4.—Typical fruit wood branch in natural position.

which the physiology has been much less studied than that of deciduous trees, and with which practical experience has been much less extensive. In addition, the California citrus fruit grower is dealing with tropical evergreens which are being grown under conditions decidedly unnatural to them. There is considerable evidence that citrus trees as grown in the arid southwest are subject to certain strains, incident to their lack of adaptation to environmental conditions, which cause disturbances of one kind or another. The 'June drop,' splitting of the fruits, puffing of the fruits, 'dry' fruits, and other similar troubles appear to be evidences of deficient adjustment to the environment.

Bud Mutation.—The genus *Citrus,* moreover, appears to be peculiarly unstable and erratic, with a decided tendency to degeneration which is seemingly accentuated under the climatic conditions of the arid southwest. The Washington Navel variety, in the half century it has been grown in California, has given rise to a number of easily recognizable strains, of which the best known are the Golden Nugget, the Golden Buckeye, the Navelencia, and the Thompson Improved.

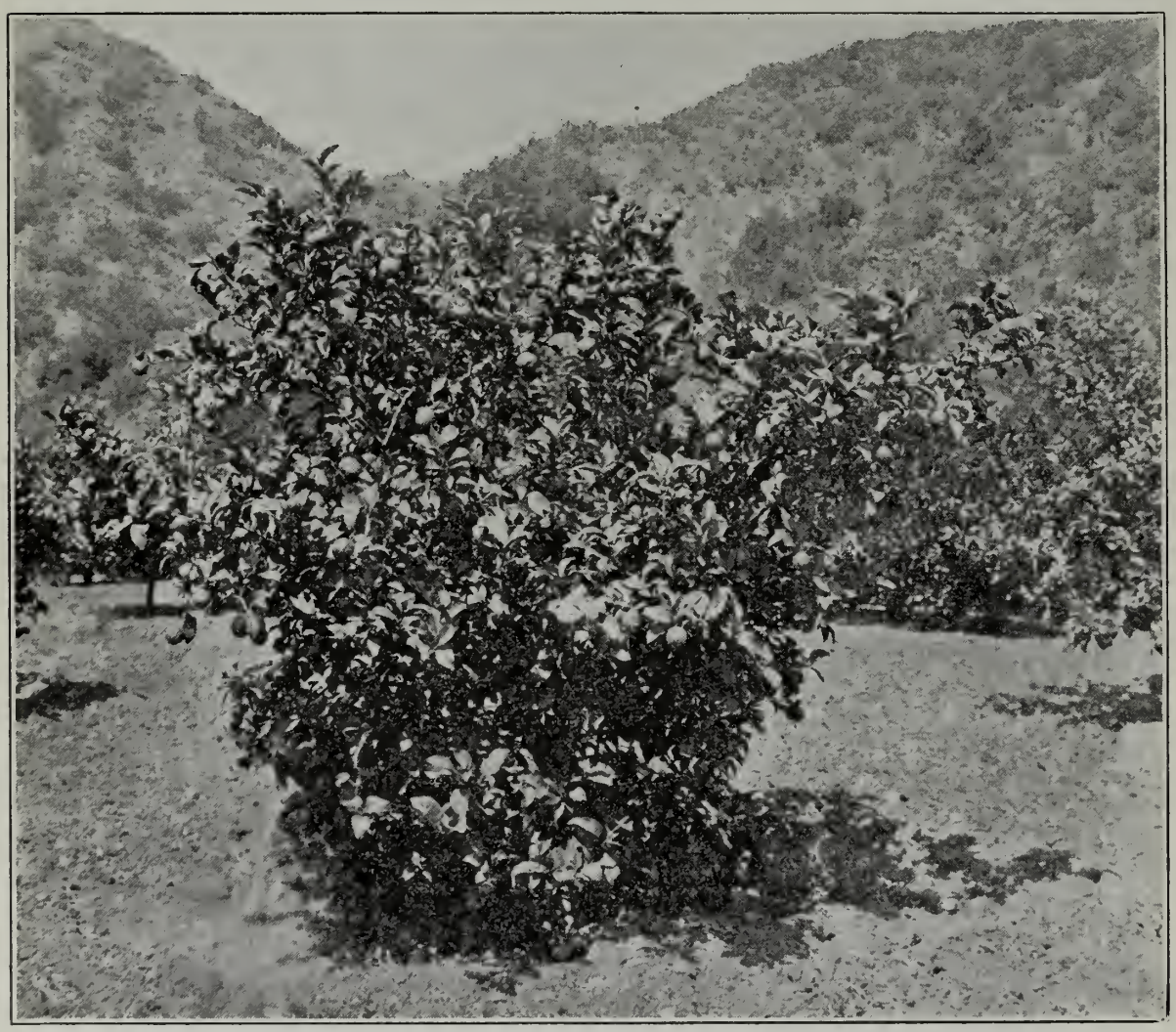

Fig. 5.—Well-pruned four-year-old lemon tree, propagated from high producing parent tree. Precocious and requires little pruning. Note the uniform distribution of fruit.

These are generally regarded as having originated as bud sports, which are known to be of rather common occurrence in citrus varieties.* The characters involved in mutations, however, may be

* In this connection it may be well to point out that many of the peculiar forms which are commonly regarded as bud sports are in reality chimeras, as they consist of purely mechanical mixtures of tissues from two distinctly different varieties. Trees of this character frequently exhibit the characteristics of the component varieties in widely differing degrees in fruits on the same branch. The origin of chimeras in *Citrus* is in all probability rather common as the result of shoots developing from adventitious buds at the bud union or subsequent to top working.

other than visible differences in color, shape or quality of the fruit, and may consist of such qualities as earliness and amount of yield, as well as others. This propensity to bud sporting and the careless propagation methods used until only recently, undoubtedly bear a causal relation to the generally known fact that the majority of the

Fig. 6.—Fruit wood branch giving rise to vegetative 'rider,' which should have been removed before reaching the size shown.

bearing citrus orchards at the present time consist of a conglomerate mixture of different strains, some of superior merit and some decidedly inferior. Each strain reacts somewhat differently, with the result that the pruning problem is thereby greatly complicated.

Polymorphism.—Another confusing factor is the property possessed by the genus *Citrus,* in common with certain other classes of

plants, of producing juvenile forms of growth, sometimes referred to as polymorphism. Nearly all citrus varieties have this tendency, though it appears to vary markedly with different strains. Little is known concerning the causes of this phenomenon, but there are many growers and nurserymen who believe that buds from these different growths have the inherent tendency, at least under certain conditions, to produce the kind of growth of the parent shoot. They do not regard this phenomenon as related in any way to bud sporting as referred to above, pointing out that it would be the rarest coincidence if two bud mutations occurred which were exactly alike, whereas many citrus varieties give rise to certain easily distinguishable kinds of growth which are very much alike in all trees of a given variety or strain. Practical recognition of this peculiar characteristic is evidenced in the fact that many reputable nurserymen and propagators studiously avoid taking buds from any type of growth excepting the actual fruit-bearing wood, it being the feeling that only by so doing can they be certain that the best type will be perpetuated.

A satisfactory explanation for the phenomenon of polymorphism is as yet lacking, and it must be admitted that the evidence thus far adduced with reference to claimed inherent differences in polymorphic forms is altogether insufficient to prove the claim. There is need for carefully conducted investigational work with reference to this whole problem and until such work is done we may not reasonably expect to determine this point.

Citrus growers and pruners in general recognize two classes of growth normally produced by citrus trees, fruit wood and vegetative growth, the latter being frequently further divided into several subclasses of an intermediate character.

Fruit Wood.—Nearly all growers recognize fruit wood as a slow-growing, pendant, small-leaved, fine-stemmed type of growth which fruits early and abundantly (fig. 4). Trees propagated from or made up largely of this type of wood are thought to be slow in growth but precocious, bearing god crops at three and four years of age (fig. 5). This type, on account of its slow growth and pendant nature, is strong mechanically and is little subject to breakage. It is a rather common opinion that trees propagated from fruit-wood buds require less pruning than trees propagated from buds taken from vegetative types of growth, as it is claimed that they have much less tendency to give rise to these growths. The fruit produced on such trees is also thought to be of superior quality, and is believed by many packing house managers and growers to hold up in storage and transit better than the fruit produced on other types of growth.

Vegetative Growth.—All other types of growth normally found in citrus trees may be regarded as vegetative in character. Specifically, however, most growers recognize these growths to be vigorous, fast-growing, characteristically upright, with large leaves, coarse-grained, and with a characteristic terminal fruiting tendency (figs. 6, 7, 8, and 9). Trees composed predominantly of vegetative growth seem-

Fig. 7.—The end of a long sucker, showing the characteristic 'tasseling-out' and fruiting when exposed to light.

ingly have a tendency to rapid growth and reach large size at an early age (fig. 10). They are said to be slow in coming into bearing on account of their strong vegetative tendency. Vegetative growth is weak mechanically because the rapidity of growth results in large, thin-walled cells. The fruit is borne mainly on the ends of long fishpole-like branches and is subject to scarring from wind injury. This results in a decreased percentage of choice and fancy grades.

The weight of the fruit causes the long spindling branches to bend down to a horizontal position, as a result of which a new series of similar shoots is produced which in turn bear fruit at the ends and bend down. It is claimed that while the amount of fruit borne by such trees may be large in the aggregate, the percentage of saleable fruit is usually low. The tendency, especially during the early years, according to the claims made, is to bear coarse fruit, although the quality generally improves as the trees age.

THE 'SUCKER'*

Much has been said for and against the 'sucker,' and much confusion exists in the minds of growers concerning it. Fundamentally, the sucker is a parasitic branch in the tree. But it may not always remain so; in fact if not removed it usually eventually becomes self-supporting and frequently becomes a valuable branch in the tree. During early life its leaf area and exposure to light are such that, like the young tree or the older tree deprived of a part of its leaf surface, it expends its energies in vegetative growth at the expense of fruiting. This explains the fact that the sucker grows long and slender while shaded by the outer foliage of the tree. But as soon as it reaches the light, carbohydrate manufacture increases to the point where normal fruitfulness occurs and the sucker produces bloom and sets fruit (fig. 7). Keeping the trees sufficiently open to permit moderate light penetration will do much to prevent the growth of suckers in citrus trees, causing them to become interior fruit-wood branches instead. Suckers may be induced to branch and fruit by repeated cutting, which accomplishes the slowing down of the rate of sap flow. A pruning axiom generally accepted among growers is that the best and most fruit is produced on much-twisted and jointed horizontal growth where the sap flows slowly. Measurements made in rapidity of sap movement in sucker growth and fruiting wood tend to support this idea. A much more rapid rate of sap flow has been shown to occur in the sucker than in fruit wood.

* The word 'sucker' as used here refers to the strongly vegetative shoots so commonly found in citrus trees, rather than to the more exact definition of 'suckers' as strongly vegetative shoots arising from the trunk or main branches as distinguished from 'water sprouts' arising from the smaller branches or the outer parts of the tree.

Fig. 8.—A typical 'sucker' allowed to run wild in a young Washington navel tree. This sucker is heavily loaded with fruit, but is highly undesirable nevertheless.

The fact that sucker growth can be curbed and induced to fruit is utilized by certain schools of pruners who advocate the use of sucker growth for framework limbs, accompanied by selecton of the best fruit wood produced as a consequence of vigorous heading. This

Fig. 9.—Characteristic vegetative upright shoot from a young Valencia orange tree, caused by crowding and lack of attention to training treatment.

practice cannot be recommended, however, as it invariably results in the production of a number of strongly vegetative shoots which must later be removed, the production of which is a waste of the energies of the tree (fig. 11).

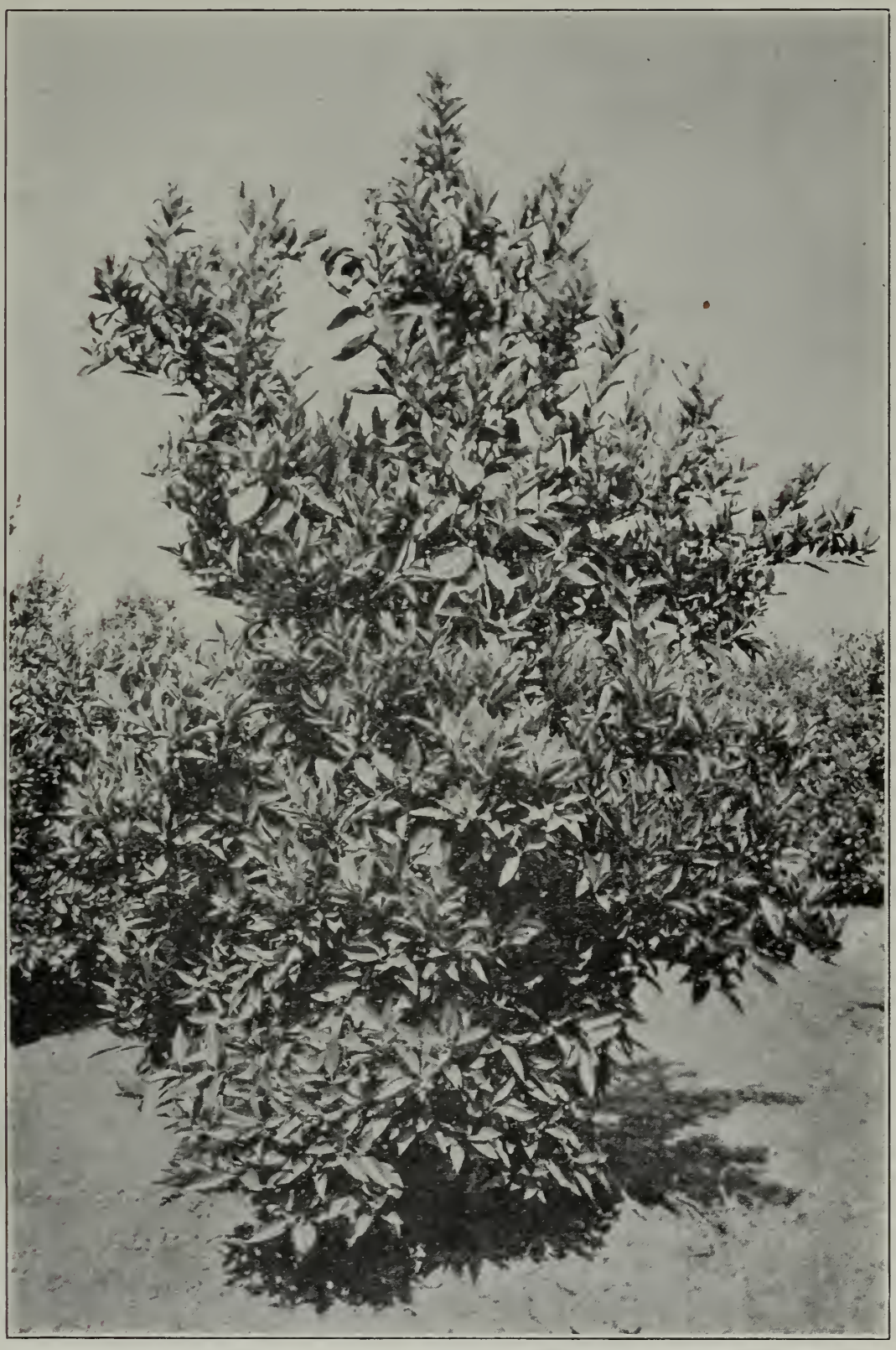

Fig. 10.—One extreme. Unpruned young Valencia orange tree showing 'two-story' effect. (See also fig. 12.)

It has long been recognized that a certain type of old tree deterioration is almost invariably accompanied by the presence, particularly in the tops of the trees, of large branches of a sucker nature. Indeed, in almost every old orchard there are tall, columnar-shaped trees, frequently referred to as 'two-story' trees, the tops of which are composed of one or more large branches which were originally suckers. These trees usually begin to decline in vigor and productivity after a few years of profitable bearing. Gradual elimination of the sucker growth has in many cases been found to result in a return to vigor and productivity on the part of trees in this condition.

There has been and doubtless always will be much speculation concerning the reasons for the occurrence of suckers. Abrupt changes of almost any sort, such as irrigation delayed until the soil has dried out, the application of considerable amounts of quickly available nitrogenous fertilizers, a period of high atmospheric temperature, and others are usually followed by the production of suckers. By far the most common cause, however, is pruning treatment which disturbs the nutritional balance of the trees. The amount of such growth is usually in direct proportion to the severity of the pruning treatment. Trees composed largely of decadent branches, and trees affected by certain little understood diseases of the 'mottled-leaf' type, are especially prone to produce suckers, lending weight to the belief that the sucker is frequently an attempt at tree renewal. It is unquestionably true, however, that trees regularly and moderately pruned have much less tendency to the production of sucker growth than trees unpruned or spasmodically given severe pruning treatment, emphasizng the belief that the regulation of light is probably a factor of great importance in controlling the production of suckers.

Suckers, therefore, while in many cases undoubtedly possessing the same inherent characters as fruit wood, are during their early life parasitic, almost invariably mechanically weak, and frequently subject to early deterioration, for which reasons they may be regarded as of doubtful utility in the economy of the citrus tree. A realization of this fact is evidenced by the best pruners, who are inclined to rigorously exclude them.

Fig. 11.—Vigorous upright vegetative growth invariably follows heading back. Note the fact that all the fruit is on the low-hanging unpruned branches.

AGE OF FRUITING WOOD

There is a feeling among citrus growers, supported by considerable evidence, that as fruit bearing wood ages, it gradually declines in fruitfulness. An observation that was very commonly made following the 1912–13 freeze strongly tends to confirm this idea. Many trees which had to be rather severely pruned after the freeze and from which normal crops were not expected for several years, to the surprise of growers bore good crops the following year and the second year after the freeze in many cases carried more fruit than had been produced for years. This behavior apparently shows the desirability of a periodical renewal of the bearing area of the trees. Unquestionably, the cause of low yields in the case of many of the older orchards is the absence of vigorous, healthy fruiting wood, a defect which can be remedied only by means of proper pruning treatment. Ample evidence is at hand to show the importance of stimulating the production of new interior fruiting wood, it being generally recognized that after two or three years of fruit bearing this wood loses the fruiting habit.

PRUNING THE YOUNG TREE

Since the primary object of the citrus grower is the production of fruit, pruning treatment during the early years should be of such a character as to encourage the development of a strong and vigorous tree with a large bearing area which will fruit at as early an age as is consistent with the health of the tree. Experience has clearly indicated that the accomplishment of these objects is invariably accompanied by a minimum of pruning. It is certan that severe pruning treatment during the early years results in dwarfed trees and delayed fruiting (fig. 12).

With practically all varieties, however, a certain amount of training is necessary if proper framework formation is to be secured, and attention to this need is a matter of the greatest importance for the future welfare of the tree. Unless carefully attended to during the first three years after planting, the young citrus tree is almost certain to develop a decidedly poor framework. The tendency is for the main scaffold branches to arise at or about the same place on the trunk. This is encouraged by the nursery methods used at the present time in forming the heads of the trees. If the heads are not thinned out, in later years pinched branches and weak crotches are certain to result. During the first two or three years in the orchard special

attention should be given to the selection of framework branches which can grow and develop so that later in life it will not be necessary to remove them in order to prevent crowding.

From three to four main scaffold limbs should be selected, distributed as evenly about the trunk as is possible in order to secure balance and symmetry and distributed vertically over as much space

Fig. 12.—Another extreme. Young Valencia orange tree of the same age as that shown in figure 10, but dwarfed by severe pruning. No opportunity to grow.

as is available in order to secure a maximum strength. Crossing scaffold limbs should always be avoided. If they are selected early and those not desired are repressed by pinching or thinning, it is rarely necesary to head back these main leaders. In case this becomes necessary they should be shortened in to laterals, if possible. All remaining branches should be left unpruned with the exception of unduly long and vigorous shoots, which may be shortened in or

removed with advantage. A mistake very commonly made is the clipping off of the ends or the removal of the long slender hanging branches on the lower parts of the trees. These should be allowed to remain for the first few years, as they constitute the principal source of revenue during the early life of the trees.

When the framework branches are established, about all the pruning the young tree should receive is the removal of suckers from the trunk and of unusually vigorous water sprouts from the head together with the elimination of crossed or interfering limbs, and, where convenient, some attention to the preservation of symmetry. Unusual care in spreading the framework branches of the young citrus tree is neither necessary nor desirable. In certain districts there is too much tendency to try to accomplish this while the tree is in the formative stage. Many a flat, spreading, undersized tree could have been made to produce larger crops by encouraging a more upright development while it was young, getting the required spread afterwards. Occasionally a light or moderate opening up where the growth is becoming too dense is desirable. Just as in the case of the bearing tree, the tendency in the past has been to prune the young tree entirely too much. It is certain that this tendency has cost the citrus growers of California many hundreds of thousands of dollars and especially is this true of the practice long followed of removing the long slender hanging branches which bear the major part of the crop during the first few years (fig. 5). A good rule to follow, especially in the pruning of young citrus trees, is *when in doubt, leave it.*

For the best results both in framework formation and in conserving the energies of the young tree, it should be given attention at frequent intervals. For the first three years it should be gone over at intervals of two to three months.

The Navel Orange and Grapefruit.—The Washington navel orange and Marsh grapefruit have very similar habits of growth and usually give very little difficulty during the first few years. Pruning should be confined to the elimination of the characteristic strong-growing water sprouts which if not removed will result in ill-formed, lopsided trees (fig. 8) and the removal of sucker shoots.

The Valencia Orange.—This variety has a much more vigorous habit of growth than the navel orange or grapefruit and requires more attention during the early years, if well-formed trees are to be secured. The Valencia orange is an upright grower and if unpruned or poorly pruned will early develop into a tall, columnar or cylindrical

tree, the upper part of which is composed of a mass of long slender, broom-like shoots, which, as they begin to carry fruit, bend down, pulling the trees out of shape, and are subject to much breakage unless propped or supported by wires (fig. 10). Attention to the matter of proper framework formation is therefore of especial importance with this variety.

The Valencia orange has a natural tendency to produce a vase-shaped tree. This tendency should be encouraged by training. Usually during the first season after planting from six to ten or more vigorous upright shoots arise from the original head of the tree. If not properly cared for, these shoots give no end of trouble. Unless thinned to from three to five in number, they are certain to grow long, slender and weak (fig. 9). While still small they should be thinned, taking care to leave only those with a good attachment. These should be watched carefully and where they make too much length growth should be shortened in to a lateral branch if possible, and if laterals are not present, should be headed back moderately. Heading back is best done after the shoot has matured somewhat and should not be done while it is soft and growing rapidly. It is possible, however, to stop length growth in soft rapidly growing shoots by pinching out the tips. These shoots serve to form the future framework of the tree and should be given frequent inspection and attention during the first three years.

Shoots not needed for framework formation should not be pruned unless too long and vigorous or interfering with the scaffold limbs. The tall, upright shoots which are so characteristic of this variety present a puzzling problem to many pruners and a rather common practice is to remove them entirely, leaving only the fine-stemmed, more or less pendant fruit wood. The removal of these shoots is clearly a mistake and results in dwarfed trees and delayed and light fruiting (fig. 12). If left alone such shoots soon 'tassel out' at the ends, bend down, and start fruiting. Indeed during the first few years the branches developed from these shoots normally carry most of the crop. Eventually all of them must be removed, though some will remain for years as good fruiting branches.

The Lemon.—The lemon, like the Valencia orange, is more vigorous in growth than the navel orange or grapefruit, and requires much the same treatment during the early part of its life. Indeed usually it requires even more care during this period, since its growth propensities vary so greatly with different soil and climatic conditions. Furthermore, nearly all lemon strains are decidedly more

polymorphic in character than other citrus varieties. An unpruned young lemon tree is almost certain to develop largely a rank-growing and mechanically undesirable type of growth.

Being a rapid grower, the young lemon tree should be given close attention with respect to framework formation. In districts where soil and climatic conditions do not accentuate vegetative growth, selection of suitable scaffold limbs, all others being pinched back, will usually be found to give satisfactory results. On rich, fertile soils, however, and under climatic conditions which stimulate growth, it is necessary to follow the treatment recommended for the Valencia orange if a sufficiently compact and sturdy framework system is to be secured. This requires shortening in the scaffold limbs, which should always be done to a lateral branch if one is available. It is easy, however, to go to extremes in this regard, with the result of accentuating the vegetative tendency and delaying the period when the tree should come into profitable bearing. Especial care should be taken to encourage the development of upright scaffold limbs, as otherwise the weight of fruit will later pull these branches down and the final result will be a low, flat tree with a deficient bearing surface.

Heading-in or tipping shoots not used for framework formation is just as injurious as in the case of the Valencia orange. Such branches should be left alone as they constitute the principal source of fruit during the early part of the bearing period.

For the best results young lemon trees should be pruned lightly every three months during the first four growing seasons (fig. 13), the operation being confined largely to removal of shoots poorly placed or undesirable in character.

PRUNING THE BEARING TREE

If properly pruned the young citrus tree should come into profitable bearing at from four to six years of age, with a well developed framework system and good size and vigor (fig. 5). During the first few years of bearing pruning should be confined to the removal of suckers from the trunk and framework branches and the elimination of the rank-growing water sprout 'riders' from the outer parts of the tree, with the gradual removal of the first fruiting shoots from the lower part of the tree as these fail. Suckers and water sprouts should be removed while still small and before seriously draining the vitality of the tree. They should be taken out two or three times during the growing season. For the next four or five years the bearing tree will not require much in the way of pruning, but it should be given a

semi-annual inspection and such pruning treatment as its condition demands. From that time on the need for pruning usually increases gradually somewhat, although light to moderate pruning should always be the rule. Extremist methods practiced on healthy bearing trees are certain to result disastrously and moderation in treatment should always prevail.

Fig. 13.—Well-pruned two-year-old lemon tree.

As the trees age, it becomes increasingly important to regulate the light supply if healthy fruiting wood is to be maintained in the interior parts of the tree. This requires thinning out of the outer shell of foliage, which some pruners accomplish by the removal of entire branches rather than by a general thinning of the fruiting brush. Care must be taken, however, not to leave large 'holes,' particularly in the tops of the trees, or injury from sunburn may result (fig. 14). The removal of fairly large branches is almost certain to

be followed by the production of suckers in the vicinity of the cuts made. These suckers should be carefully thinned or shortened in.

Keeping the trees reasonably open to light bears an important relation not only to the maintenance of healthy interior fruiting wood but also to the occurrence of dead wod. If the trees are kept in good condition this will be reduced to a minimum. Almost invariably a certain amount of dead wood will occur and it is desirable to remove this, since such has frequently been noted to result in a general stimulation. The removal of dead wood is not a matter of vital importance, however, since it apparently undergoes a natural shedding process which prevents it from increasing beyond a certain point.

As the trees grow older, it becomes necessary to provide for the gradual renewal of the bearing area through the occasional removal of the older parts. The removal of these parts should be done gradually, however, or vigorous 'suckering' is certain to result. The first branches to lose the bearing habit are usually the lower ones which are gradually crowded out by the new growth from above. These should be taken out as soon as their condition indicates the passing of their usefulness. The removal of such branches is generally known as 'under-cutting' (fig. 15). It is not desirable to take out bodily old branches from the tops of the trees, for the resulting tendency is not to produce a new limb but to fill up the opening by the growth of new wood from adjacent limbs, and if continued this process will result in diminishing the bearing surface as well as destroying the symmetry of the tree (fig. 14). By far the better way is to remove several of the younger and smaller branches, making all cuts so that the sap flow is readily diverted into other branches. 'Stubbing' such branches should be studiously avoided, as it results in a thicket of sucker shoots practically as undesirable as the original condition.

The lower branches should not be allowed to rest on the ground. The fruit borne on such limbs is generally of poor quality and is apt to be attacked by brown rot. On the other hand the trees should not be pruned up too high, as considerable bearing area is thus wasted. The height to which citrus trees are pruned from the ground varies considerably and depends largely upon the implements used in cultivation. If the trees are pruned up a foot from the ground, provided there are no horizontal branches starting from the trunk below that height, it is possible by the use of shields on cultivating tools to work well up under the trees and at the same time to produce large amounts of fruit of good quality on the lower branches.

Regular annual pruning for the bearing tree should be the rule, rather than the present all-too-prevalent irregular practice. Frequent and regular treatment tends to preserve as nearly as possible the proper equilibrium between root system and parts above ground, which if disturbed results in the production of vigorous vegetative growth of an undesirable character which must later be removed. Further, the amount of pruning required to keep the bearing tree in good condition is reduced to the minimum by regularity of treatment, with a consequent saving of expense.

Fig. 14.—Taking out the tops of neglected or decadent trees is rarely accompanied by desirable results. Sunburn is almost certain to follow such treatment.

Heading Back versus Thinning Out.—Fundamentally all systems of pruning bearing trees may be reduced to the practices known as *heading back* and *thinning out* or combinations of the two, and a discussion of the results of these practices as they apply to citrus fruits is decidedly helpful as a basis for rational pruning.

By thinning out is meant the entire removal of a shoot, branch, or limb, as contrasted with heading back, by which is meant the removal of only a portion of such shoot, branch, or limb, leaving another portion from which new growth can develop. The two practices have decidedly different results in the case of citrus trees. Heading back invariably leads to greater shoot production than a corresponding thinning out does (fig. 11). The growth response is localized in the vicinity of the cut made, with the result that the four or five terminal

buds on the headed-back shoot are stimulated into growth, and develop into four or five long, slender, upright sucker branches, precisely what the citrus grower usually does not desire. Of these vigorous growing shoots resulting from heading back one or more may be less vegetative than the rest and may be utilized for fruit wood. The others, however, must either be headed back, in which case a repetition of the same condition occurs, or they must be taken out, thus representing energy wasted by the tree.

From the nutritional point of view, heading back changes the branch so treated from the fruiting to the vegetative condition, or if applied to a branch already vegetative accentuates this tendency. In addition, heading back promotes density and compactness, which in turn reduces the light exposure of the interior parts.

On the other hand, thinning out is accompanied by less shoot growth and is much less vegetative in character; also it does not produce any severe disturbance in nutritional balance, which might result in vegetative growth. Since it does not remove so much stored reserve and instead of promoting density encourages better exposure to light, in a general way the thinning out process is decidedly more favorable to the development of fruiting wood and to the more efficient functioning of that which is present.

From this discussion it is obvious that both practices may have a legitimate place in the pruning of citrus trees, but it is also apparent that heading back is a practice which, if utilized at all, should be followed in the early life of the tree when framework formation is the principal consideration, while thinning out is the logical practice to follow later when the problem becomes that of fruit producton and maintenance of tree vigor. As indicated above, however, with citrus trees it is rarely necessary to resort to heading back, even in the period of framework formation.

Practices to Avoid.—In addition to heading back or 'stubbing' there are certain other practices which should be avoided in the pruning of bearing citrus trees. Severe pruning of healthy bearing trees is to be condemned at all times. There is ample evidence available on this point, which shows conclusively that severe pruning of trees in good bearing not only reduces the yield but is decidedly repressive of vigor as well. These effects are due to the reduction of bearing surface and to the consequent actual carbohydrate starvation which is always correlated with marked reduction of leaf area.

The leaving of stubs where branches are removed is not only an evidence of careless work but directly encourages the production of

clusters of suckers sometimes called 'sucker nests.' Cuts should be made close to the parent limb, as this will facilitate healing over and will partially overcome the tendency to sucker growth. Vertical cuts should be made where possible, since they heal over much more readily than those made in the horizontal plane.

Shearing off the outer parts of the trees in order to secure symmetry is another practice to be avoided. In reality shearing is merely a light form of heading back and invariably results in accentuating the production of upright vegetative shoots which crowd the others and later require either thinning out or removal.

Fig. 15.—The older worn-out branches are removed by the process of 'undercutting.'

The Navel Orange.—The navel orange has two rather pronounced tendencies which must be guarded against. One is the production on the main framework branches of suckers, one or more of which are apt to develop, with a gradual crowding out of the top branches to the point where eventually this part of the tree is composed entirely of sucker growth. Where this occurs, early decline is generally the rule and the rejuvenation of such trees is usually a difficult matter. The early removal of these suckers is therefore important.

The other tendency of this variety in most districts is toward density of growth with the resulting death of the interior fruiting wood, the choking out of the lower branches, and the occurrence of an unusual amount of dead wood. The naval orange therefore requires more attention with respect to keeping the trees open to light penetration than do most other citrus varieties.

The Valencia Orange.—The vigorous upright habit of growth of the Valencia orange makes it necessary to give special attention to the curbing of the tall vertical shoots which characterize this variety. As the trees age, pruning should be directed toward the opening up of the tops in order that the interior bearing area may be fully utilized. Thinning the growth on the sides and lower portions of the trees is usually of much less importance with this variety than with the navel. Special attention should be devoted to the renewal of the fruit bearing wood in the tops of the trees, however, as the loss of the fruiting habit generally occurs first in this part of the tree.

The Tangerine.—The tangerine is naturally a tall upright tree with a spreading habit of growth. It is invariably a mistake to attempt to prune this variety to the cylindrical or spherical forms which characterize the Valencia and navel orange varieties. Heading back and shearing are especially to be avoided in pruning the tangerine. All that this variety needs is the removal of dead wood and an occasional thinning of the outer shell to encourage interior fruiting.

Other Varieties of Orange.—Usually but little attention, other than the removal of suckers and water sprouts, and an occasional moderate opening up is necessary with the remaining varieties of oranges. One exception should be noted however, viz., the Mediterranean Sweet which has so dense a natural habit of growth as to require rather frequent thinning of the outer shell of foliage and fruiting wood. In its pruning requirements this variety is markedly similar to the grapefruit.

The Grapefruit.—Ordinarily the bearing grapefruit tree requires but little pruning. Young, vigorous trees must be encouraged in the formation of a sturdy framework system, which may require some heading back of scaffold limbs. The older trees, however, usually need little more than a judicious thinning of the outer parts of the tree to stimulate interior fruiting. The grapefruit has a strong tendency to crowd out and starve the lower hanging branches. This may be overcome partially at least, by more attention to opening up the sides of the trees.

The Lemon.—Of a pronouncedly vigorous habit of growth, the bearing lemon tree in California requires considerably more pruning than any other citrus tree. Especial care should be taken to keep the trees at all times free from suckers and the 'rider'* water sprouts so characteristic of this variety. The tendency of the lemon in certain

* The term 'rider' is commonly used to designate water sprouts occurring on the upper sides of branches on the outer parts of the trees. The direction of growth of 'riders' is usually at a right angle to the parent branch.

districts and particularly on fertile soils is to produce long spindling shoots which are mechanically undesirable because they are much subject to breakage. Shortening-in of such branches to laterals is necessary to obtain a satisfactory tree. Especial care must be taken to encourage the formation of strong, upright framework branches, as the weight of fruit has a constant tendency to pull the branches down and thus form a low, flat tree. The lower branches as they are crowded down and get in the way of cultivating tools must be removed. The tops of the trees sometimes, though rarely, become so dense as to require thinning. It is of special importance, however, that the sides and lower parts of the trees be kept well opened up, since these parts of the trees if unpruned soon become so dense that the fruit becomes scarred and picking is very difficult. A natural characteristic of the lemon is the production of an unusual amount of fine interior fruiting wood, which must be periodically thinned to be efficiently utilized. Maintaining the trees reasonably well open at all times will serve to keep healthy new fruit wood coming on to replace the older parts. These should be removed as they decline and become unfruitful. To keep bearing lemon trees in good condition semi-annual pruning is necessary. With all other kinds of citrus trees annual pruning together with the removal of suckers two or three times a year will usually suffice to keep the trees in good condition.

SPECIAL CASES

The discussion of pruning in this publication thus far has had reference to the young tree from the time of planting until it reaches full bearing, assuming that at all times it has received proper care and attention. Comparatively few orchards, however, have been consistently well-pruned from the time of planting until maturity and there thus arises the necessity for a consideration of special pruning problems with which growers are frequently confronted.

Changing from Heading to Thinning.—In changing from heading back to thinning, it is necessary to bear in mind the fact that satisfactory results cannot be secured from a single pruning or within one season. It usually requires two seasons and three to five prunings to successfully accomplish the change. The most vigorous vegetative shoots should be removed first, taking especial care to cut them close to the parent limbs in order to minimize the subsequent production of similar shoots. The less vigorous vegetative shoots should be left at each pruning. If this practice is followed the resulting growth will become less and less vegetative until the trees are finally in good

balance again. Occasionally it will be necessary to leave rather vigorous shoots, but these should be shortened-in to laterals where possible. If laterals are not present it is not advisable to resort to heading back. Allowing the shoots to go unpruned for a few months will almost invariably result in the production of laterals which can be used later in the shortening-in process. For the best results in changing from heading back to thinning the trees should be gone over at least three times during the first year. If vigorously vegetative, the same number of prunings may be necessary the second year, although usually such is not the case.

Pruning the Neglected Orchard.—It should be stated at the beginning that the orchard in which pruning has been neglected cannot be brought into good condition by a single pruning. To do this requires several years and a number of prunings. An important consideration to bear in mind is that as much damage may be done by too severe pruning as by no pruning at all. It is generally recognized that the vigor of response to pruning is somewhat proportional to the amount of wood removed. Thus in trees allowed to grow up to large suckers, if all these are taken out at the same pruning, a rank, vigorous growth of sucker shoots will appear in the place of those that were removed. This is exactly the opposite of the end desired, which is to encourage the production of the slower-growing fruit wood.

It is therefore a cardinal principle in pruning neglected trees to regulate the amount of wood removed so as to distribute the response as uniformly as is possible without localizing it. To accomplish this requires a lighter and more judiciously distributed pruning than is usually given to such trees. In the case of trees containing a number of old sucker limbs, not all should be cut out at the same pruning, but only one or two, according to their size and location. Care should be taken to go over the new growth produced in response to the pruning, thinning it out where necessary and taking out all vigorously vegetative shoots. If this practice is followed, it is possible to bring trees where pruning has been neglected back into good condition within two or three years.

In the case of badly neglected trees a pruning program that can be recommended is about as follows: The first pruning should consist in removing a few of the sucker limbs and cutting back some of the remainder to smaller laterals. The second pruning, a few months later, should consist in the removal of interfering limbs and of the worst of the sucker limbs left at the previous pruning, together with a thinning out and selection of the new growth produced in response to the previous treatment. Subsequent prunings should be similar

to the second. Where such a program is used, within two or three years the tendency to the production of sucker shoots will have been largely overcome and the old and decadent parts eliminated, both these results being accomplished without seriously disturbing the equilibrium of the tree and causing a waste of its energies in the production of undesirable growth.

Fig. 16.—Sparse weakly growth in the tops of the trees usually indicates decline.

Rejuvenating Decadent Trees.—The bringing back into vigor of the many old citrus groves which are rapidly failing in productivity and health constitutes a serious problem confronting California citrus growers. As indicated in Part I, there are two principal causes for the decline of fruit trees, nitrogen starvation and carbohydrate

starvation. Both are fairly common in the citrus orchards of California. Of the two, however, nitrogen starvation is undoubtedly much the more prevalent.

The characteristics of decadent citrus trees are well known to many growers but it may be worth while to briefly enumerate them. In the order in which they usually appear they are (1) increase in the percentage of small-sized fruit (in the case of lemons accompanied by an increase of tree ripe fruit); (2) decrease in total yield; (3) dwarfed foliage, starting in the tops of the trees (fig. 16); (4) superabundance of weak or leafless fruit spurs; (5) heavy production of weak blossoms, mostly abortive; and (6) gradual development of chlorosis.

Whether the specific cause of decline be nitrogen starvation or carbohydrate starvation, rational pruning treatment may frequently be utilized with advantage in bringing the trees back to productivity. In the case of the former, the reduction of carbon assimilation accomplished by pruning reëstablishes the proper balance between nitrogen intake and carbon intake for optimum fruitfulness. Where the cause is carbohydrate starvation, proper pruning will tend to reëstablish the correct balance for fruitfulness by relieving the tree of inefficient and decadent tissues and substituting therefor new and more efficient tissue.* In the case of deficiency in nitrogen supply, however, increased fertilization with this element is undoubtedly the more rational method to use in the rejuvenation process, because it restores the nutritional balance by the addition of the deficient element, thus increasing the possibilities of production, while restoring the balance by subtraction merely utilizes the existing possibilities.

There is little agreement among growers, however, as to the best methods of pruning to use in the bringing back into vigor and productivity of decadent trees. A brief discussion of this subject seems desirable.

Deheading.—A method used in certain of the older citrus-growing sections of the world, notably Brazil, Spain, and Italy, is the periodic renewal of the tops of the trees by *deheading,* and this method has been advocated by certain investigators and practiced by a few growers in California. It is, however, open to criticism of sufficient weight to have discredited it in the minds of the majority of growers.

---

* In all probability the production of sucker growth so characteristic of declining trees is a natural means of restoring the carbohydrate balance by the activities of the new and vigorous leaves on such shoots, which thus tend naturally to renew the tree.

Tree renewal by decapitation is an extreme method and felt to be unnecessarily severe. Entire removal of the tops of the trees has a serious weakening effect on the root system, the vigor of the resulting shoots being due merely to their diminished number. If not properly cared for and given frequent follow-up treatment these are certain

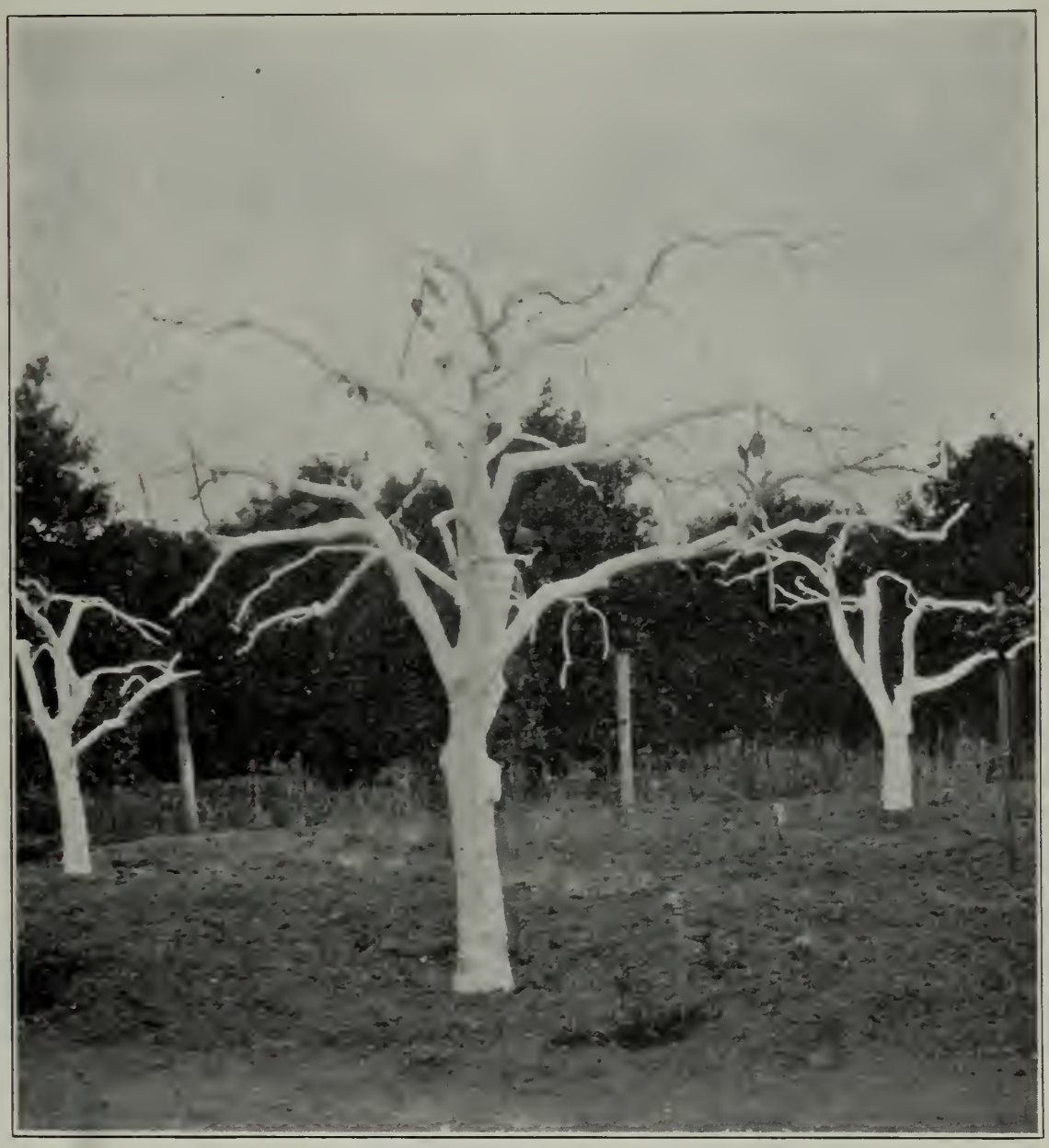

Fig. 17.—Extreme skeletonization as applied to old Valencia tree. (Photo by courtesy of Mr. E. S. Lewis.)

to grow vegetatively for several years and to result in the formation of a very undesirable framework. In addition the large wounds made rarely, if ever, heal over properly. Moreover, this severe treatment delays profitable bearing for a period of five or six years. This method never made any great appeal to California citrus fruit growers and for the reasons given as well as others is rapidly losing favor.

Dehorning.—A modified and less severe treatment, known as *dehorning* in which a part or all of the primary and secondary scaffold branches are left but cut back to stubs a foot or more in length has also been used to some extent. This method, however, differs little if at all, except in severity, from the head removal system and for the same reasons is losing favor.

Skeletonizing.—A much more rational method, and one which has apparently given quite satisfactory results in the rejuvenation of old trees is that best described as skeletonizing. In this method the entire framework system of the tree is left, except in cases where too many scaffold limbs were allowed to develop originally, in which event one or more of these are removed entirely. All crossed limbs and unnecessary leaders are removed, and what remains is the simplest possible skeleton on which to build an entirely new fruiting system (figs. 17, 18, and 19). The height and diameter of the tree are reduced little, if at all, but all the small branches and shoots are removed. 'Stubbing' or heading back to branches larger than an inch or so in diameter is studiously avoided.

Numerous cases where old orchards have been pruned by this system have shown that within three to four years the trees have entirely recovered, are in good vigor, and yielding heavier crops than ever (figs. 17 and 18). The degree of severity with which this system should be applied varies somewhat and obviously depends upon the extent of decadence existing at the time the pruning treatment is used.

All things considered, the skeletonizing system of pruning for tree rejuvenation appears to be the most rational as well as successful for a number of reasons. This treatment distributes the pruning response throughout the entire framework instead of localizing it in certain parts of the tree. It is generally recognized that the response to pruning treatment is largely confined to the region where the removal of parts has occurred. Thus taking out or heading back branches in the tops of the trees, a practice much used in the past, does not stimulate growth in the rest of the tree, but results in a vigorous growth of vegetative shoots on the branches near the cuts and necessitates frequent subsequent thinning.

Since the response is widely distributed by this system of pruning, the amount of follow-up work is greatly reduced. Moreover, the growth resulting is not markedly vegetative, and shortly becomes fruitful, a condition greatly desired by the grower who is naturally anxious to have the trees come back into bearing as soon as possible. While this system necessitates more cuts and requires more time and

is consequently more expensive than the other systems described, for the reasons given, it appears to be preferable to them.

Pruning Frost-Injured Trees.—The subject of pruning frost-injured trees is one of periodic interest to California citrus growers. At present, comparatively little reliable information is available on this subject. Test plots now under observation where different pruning treatments, varying in method and in degree, are being used, will probably furnish this much-needed information within a few years.

Fig. 18.—The same tree as in figure 17 two seasons later, showing remarkable recovery. (Photo by courtesy of Mr. E. S. Lewis.)

There is ample evidence available, however, to demonstrate clearly that under most conditions of injury the safest procedure during the season following the injury is to discontinue all pruning treatment. It is certain that pruning is inadvisable for some months after a freeze, since it is ordinarily three to four months before it is possible to determine what the extent of the injury is. Until this can be definitely determined, pruning treatment is merely a guess; it may be too severe, or it may not extend back far enough.

Where the injury has been appreciable and extends beyond the mere loss of foliage to the death of fruit-bearing wood the effect of a freeze is very similar to that of heading back, and the response is vegetative growth. To prune at this time merely accentuates the situation and instead of aiding in restoring the balance between root system and top only further aggravates the lack of equilibrium. It therefore appears desirable to discontinue pruning until the trees have recovered from the injury, and experience has clearly shown the wisdom of this practice. Usually full recovery from the injury is not made until rather late in the season, at which time pruning is inadvisable as it increases the danger from frost injury the following winter. For these reasons it appears desirable to delay pruning frost-injured trees until a full season has elapsed.

Pruning Gophered Trees.—Pruning treatment for gophered trees is determined by the extent of injury, the period elapsing since the injury occurred, and remedial treatment provided. Where trees are practically girdled remedial treatment either by inarching, bridge grafting, or other means is necessary if they are to be saved. If such treatment is provided immediately no pruning is required.

If the injury is not extensive and natural recovery is relied upon, a moderate thinning of the top is desirable in order to restore as nearly as possible the balance existing between the root system and the parts above ground.

If the injury is not detected for some time, and the condition of growth indicates a serious disturbance, it appears to be desirable to remove a part of the top, regardless of the extent of the injury. The character of the *remedial treatment* to be later applied, however, is determined by the extent of the injury. Where the injury is extensive and the condition of the trees decidedly weak, skeletonizing may be necessary if they are to be saved. Where such is the case, however, it is questionable whether the trees are worth saving, even though it be possible to do so.

TIME OF PRUNING

Few data are available concerning the effects of pruning citrus trees at different seasons of the year. So far as is now known the response of the trees is practically the same regardless of the season when the pruning is done.

It is generally recognized, however, that pruning in late summer or early fall is undesirable, since it encourages vegetative growth and delays the maturing of the wood, thus rendering the trees more susceptible to injury from frost (fig. 20).

The bark on the shaded limbs of citrus trees is very susceptible to sunburn and equally so to injury by low winter temperatures. This renders it decidedly hazardous to do any bulk pruning, where large limbs are removed, during the hot summer season or during the winter period when low temperatures are likely to occur. For security such treatment should be given during the spring or early summer.

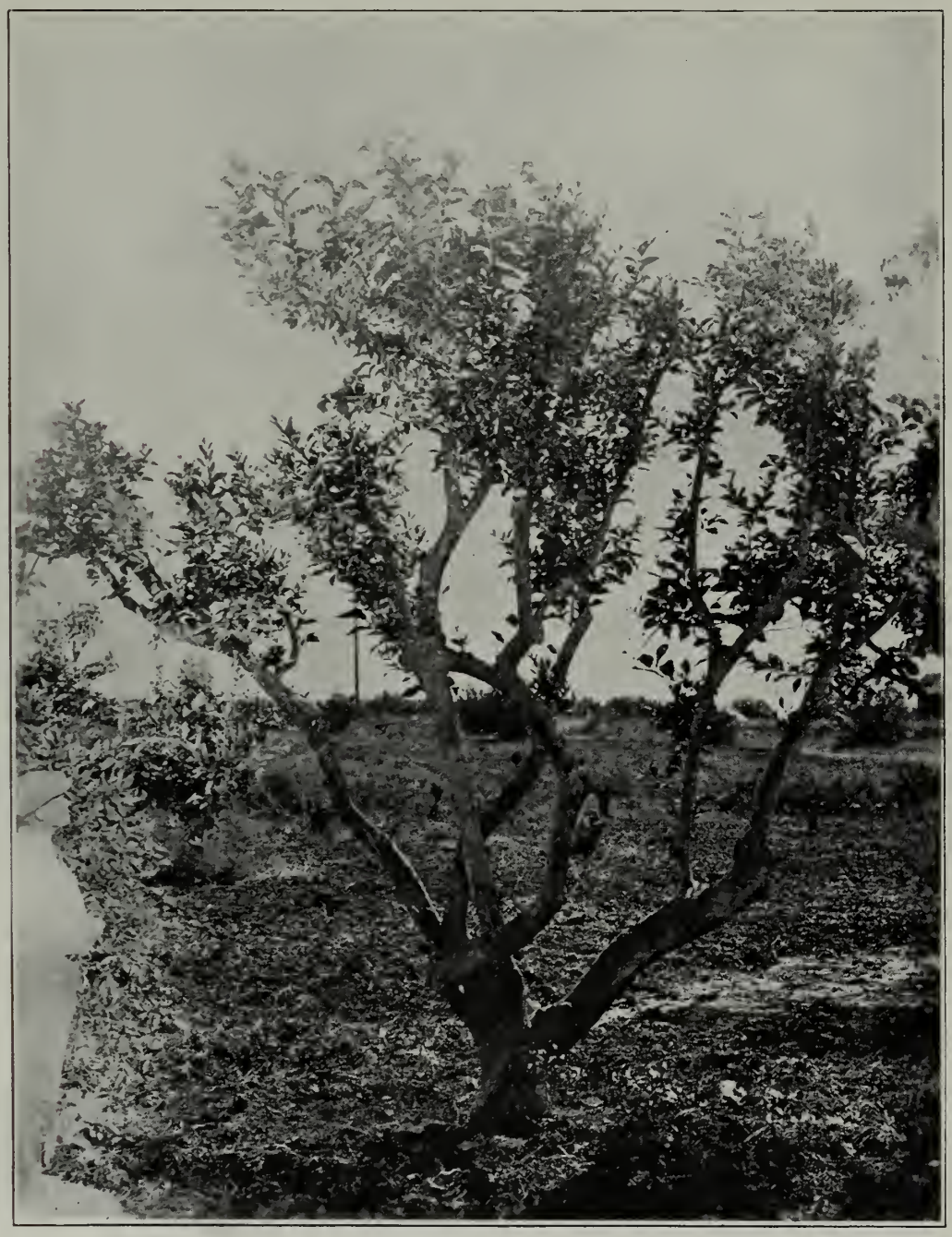

Fig. 19.—Skeletonization as applied to thirty-five-year-old decadent lemon tree.

With bearing trees reasons of convenience largely determine the time of pruning. The most important reason is the presence of maturing fruit on the trees. Thus it is the common practice to prune the trees after the crop is harvested in the case of the navel orange and grapefruit, or when there is the least amount of saleable fruit on

the trees in the case of the Valencia orange and the lemon. The pruning of navel oranges is therefore largely done during late winter and early spring; Valencia orange and lemon pruning during the summer months.

Pruning neglected bearing trees and pruning for tree rejuvenation should be done during the late winter and spring months, although sometimes it can be done with advantage in early summer.

Fig. 20.—Old lemon trees severely pruned in late fall. Properly protected against sunburn, but so badly injured by frost as to necessitate removal.

PROTECTING THE PRUNED TREE

Sunburn.—The bark of citrus trees is very susceptible to injury from sunburn and, where the injury is extensive, recovery is exceedingly rare. A few hours' exposure to the hot sun may be sufficient to cause irreparable injury. Protecting the trees against sunburn, therefore, is a matter of great importance to the citrus grower.

In all cases where pruning results in exposing framework branches to direct sunlight, even though only for a few hours during the day, such limbs should be thoroughly coated with whitewash. Whitewashing is especially important where heavy pruning incident to tree rejuvenation is done (fig. 20).

There are many satisfactory whitewash formulas. One of the simplest and best, however, is as follows:

Quicklime (unslacked or rock lime)	7 pounds
Powdered sulfur	2 pounds
Salt	1 pound

Slake together, using sufficient water to accomplish uniform and thorough slaking; then dilute to the desired consistency. *Allow to stand overnight before using.*

Wounds.—Wounds made in pruning afford opportunity for the entrance of decay-producing fungi which under favorable conditions occasion heart rot of the trees and ultimately cause serious disturbances and even death. In the dry interior valleys, the danger of decay is not so great, although always present. It is desirable, therefore, both as a means of protection as well as to encourage rapid healing over to cover all cut surfaces greater than two inches in diameter with some antiseptic dressing. The application of a disinfectant dressing prior to the use of a wound covering is advocated by some, while others maintain that just as good results are experienced without disinfectants. In case such are desired the best that can be recommended at the present time is mercuric cyanid dissolved in equal parts of ethyl alcohol and water in the proportion of one part of cyanid to 1000 parts of the alcohol-water solution. Whether disinfectants are used or not the wounds should be allowed to dry thoroughly before applying the wound dressing.

There are several requirements for a satisfactory wound dressing, the most important of which are cheapness and permanency. Other requirements include lack of penetration, and elasticity. Whitewash, bordeaux paste, lead paints, and varnishes or shellacs do not satisfactorily meet these requirements, since they soon dry out and lose their protective qualities. Grafting wax. while excellent in many respects, is too expensive at present prices for beeswax.

The most promising class of available materials are the asphaltum compounds. Asphaltum roof paint has been used by some with good results. Grade B asphaltum, a liquid form, is popular with some growers. A liquid preparation made by dissolving asphaltum in gasoline or distillate is recommended by certain authorities. Boiled coal tar has been used and is still used to some extent, and there are a number of commercial preparations on the market. Probably the best dressing for the purpose is still to be worked out.

The important thing, however, is to make certain that all wounds of an inch or more in diameter are well coated with some dressing which is renewed occasionally when this is found by inspection to be necessary.

PRUNING TOOLS

Without good tools satisfactory pruning is impossible and much poor pruning is directly due to a lack of recognition of this fact. A wide variety of tools may be found in use by citrus pruners, but experience has indicated that the following are best adapted to their needs:

1. A short, light, self-supporting stepladder.
2. One pair strong leather gloves.
3. One strong pair six-inch hand shears.*
4. One leather case for these shears, attached to belt.
5. One fourteen-inch bracket saw† (six extra blades).
6. One curved blade folding pruning saw of the pull type.‡
7. Bucket of wound compound with brush.

The saw in most general use is a pull saw with a blade eight to twelve inches long, the cutting edge of which has a curved shape. There are many types of this saw on the market; a number of these, however, have too much curve to the blade. For the removal of large crowding limbs these are not well adapted and the saw most commonly used is one of the bracket pattern with a twelve to fourteen-inch swivel blade, sometimes known as the California pruning saw. Some pruners carry both types of saws in their outfits, but the usual outfit contains only one saw.

Hand lopping shears have fallen into disfavor on account of their tendency to split the limbs below the point where the cut is made.

ACKNOWLEDGMENTS

The author desires to express his appreciation to Dr. L. D. Batchelor, Dr. H. S. Reed, and Dr. H. J. Webber, all of the Citrus Experiment Station at Riverside, and to Professor W. P. Tufts and Dr. W. L. Howard of the Agricultural Experiment Station at Berkeley for many helpful criticisms and suggestions, and especially to Professor F. T. Bioletti for his careful revision of the manuscript and his interest in its preparation.

* Rieser pattern preferred.
† Bishop pattern recommended.
‡ Choice between Tyler and Atkins patterns.